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(54) **COLOR MANAGEMENT SYSTEM USING MEASURED DEVICE DATA**

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(52) **U.S. Cl.** **358/1.9**; 358/523

(58) **Field of Classification Search** 358/1.9, 358/1.6, 1.8, 1.15, 523, 524, 520; 710/1, 710/5, 6, 7; 382/162
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,257,097 A * 10/1993 Pineau et al. 358/500
5,313,267 A * 5/1994 MacFarlane et al. 356/405
5,365,353 A 11/1994 Kraft 358/518
5,416,890 A * 5/1995 Beretta 345/590
5,608,549 A 3/1997 Usami 358/530
5,615,282 A 3/1997 Spiegel et al. 382/167
5,748,858 A * 5/1998 Ohtsuka et al. 358/1.9
5,754,184 A * 5/1998 Ring et al. 345/604
5,778,106 A 7/1998 Juenger et al. 382/275
5,806,081 A * 9/1998 Swen et al. 715/528
5,818,960 A * 10/1998 Gregory et al. 382/167
5,835,627 A * 11/1998 Higgins et al. 382/167
5,949,962 A 9/1999 Suzuki et al. 395/109
5,999,703 A 12/1999 Schwartz et al. 395/109
6,037,950 A * 3/2000 Meir et al. 345/427
6,062,137 A * 5/2000 Guo et al. 101/171
6,088,038 A 7/2000 Edge et al. 345/600
6,108,442 A 8/2000 Edge et al. 382/167
6,128,415 A * 10/2000 Hultgren et al. 382/276
6,249,315 B1 * 6/2001 Holm 348/251
6,282,313 B1 * 8/2001 McCarthy et al. 382/162
6,343,295 B1 * 1/2002 MacLeod et al. .... 707/103 R
6,362,808 B1 3/2002 Edge et al. 345/601
6,456,293 B1 * 9/2002 Grandy 345/591
6,456,340 B1 * 9/2002 Margulis 348/745
6,480,299 B1 * 11/2002 Drakopoulos et al. 358/1.9
6,603,483 B1 * 8/2003 Newman 345/593
6,628,822 B1 * 9/2003 Nakabayashi et al. 382/162
6,628,826 B1 * 9/2003 Gilman et al. 382/167
6,633,668 B1 * 10/2003 Newman 382/166
6,671,067 B1 * 12/2003 Adam et al. 358/1.6
6,704,442 B1 * 3/2004 Haikin et al. 382/162

(Continued)

OTHER PUBLICATIONS

"Graphic technology—color reflection target for imput scanner calibration", NPES The Association for Suppliers of Printing and Publishing Technologies, ANSI IT8.7/2-1993, Jun. 21, 1993, pp. 3, 12-14, 18-29.

(Continued)

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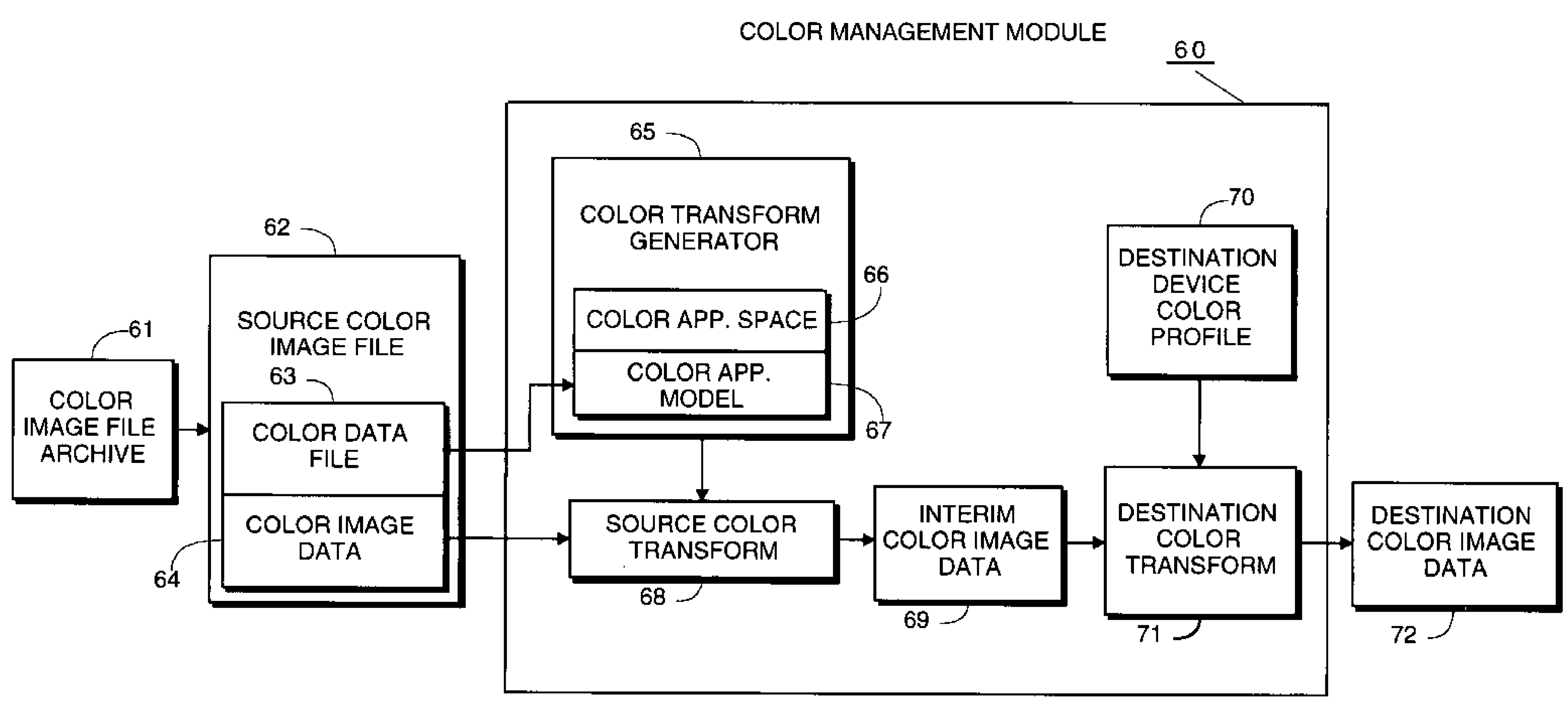
(74) *Attorney, Agent, or Firm*—Fitzpatrick, Cella, Harper & Scinto

(57) **ABSTRACT**

Managing color data to transform source color image data from a source device into destination color image data for rendering by a destination device, including accessing a source color data file corresponding to the source device, the source color data file containing source device color characteristic data, constructing a source color transform based on the source device color characteristic data contained in the source color data file, and applying the source color transform to the source color image data to transform the source color image data from a source device color space into interim color image data in an interim color space.

33 Claims, 9 Drawing Sheets



U.S. PATENT DOCUMENTS

6,873,434	B1 *	3/2005	Kohler et al.	358/1.9
6,954,286	B1 *	10/2005	Muramoto	358/1.9
2002/0154325	A1 *	10/2002	Holub	358/1.9
2003/0053682	A1 *	3/2003	Haikin et al.	382/162
2003/0053683	A1 *	3/2003	Newman et al.	382/162

OTHER PUBLICATIONS

"Argyll Color Management Project", (visited Oct. 19, 2000) <http://www.web.access.net.au/argyllcmm.html>, 5 pages.

Gill, Graeme W., "Argyll Color Correction System: Simple CMYK Profile Generator", Nov. 9, 1996, 7 pages, 1996 ©.

Gill, Graeme W., "Argyll Color Correction System: Test Target Chart Generator", Sep. 28, 2996, 9 pages, 1996 ©.

Gill, Graeme W., "Argyll Color Correction System: PostScript Print Chart Generator Module", Sep. 28, 1996, 17 pages, 1996 ©.

Gill, Graeme W., "Argyll Color Correction System: DTP51 Target Chart Reader", Oct. 4, 1996, 11 pages, 1996 ©.

Gill, Graeme W., "Argyll Color Correction System: Scanin: Input the scan of a test chart, and output cgats data, Uses scanrd to do the hard work", Jan. 29, 1997, 9 pages, 1995 ©, 1996 © and 1997 ©.

Gill, Graeme W., "Argyll Color Correction System: CMYK Device Profile Generator", Feb. 15, 1997, 5 pages, 1996 ©, 1997 © and 2000 ©.

"File Format for Color Profiles", International Color Consortium® Specification ICC.1:1998-09, © 1998.

Fairchild, Mark, Tutorial Notes from The Seventh Color Imaging Conference, "T3, Color Appearance Modeling and CIECAM97s", pp. 7-9, Nov. 1999.

"Discussion on papers dealing with colour-profiles, file compression and colour management systems," Proceedings of the CIE Expert Symposium '96 Colour Standards for Image Technology, Mar. 25-27, 1996.

* cited by examiner

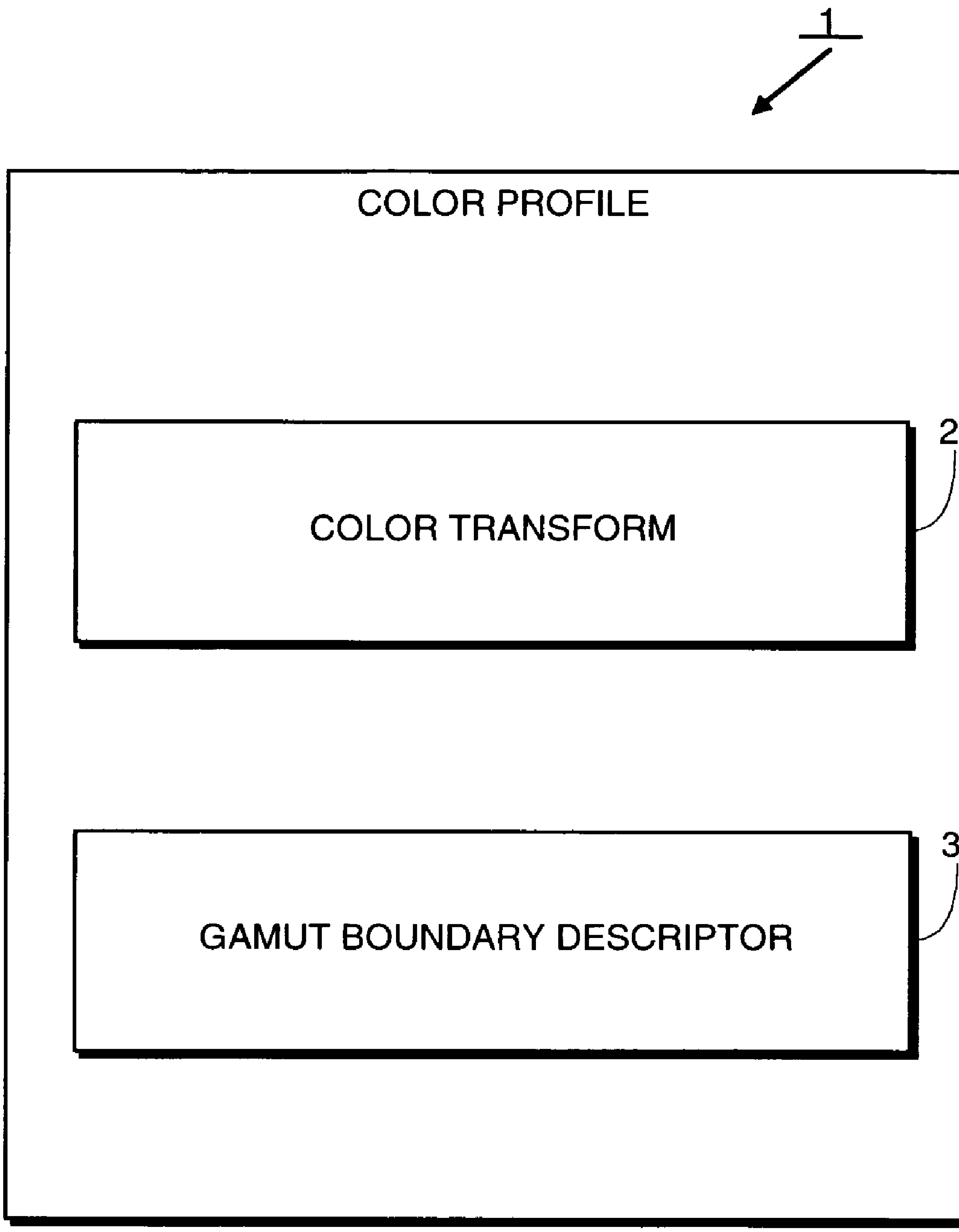


FIG. 1
(PRIOR ART)

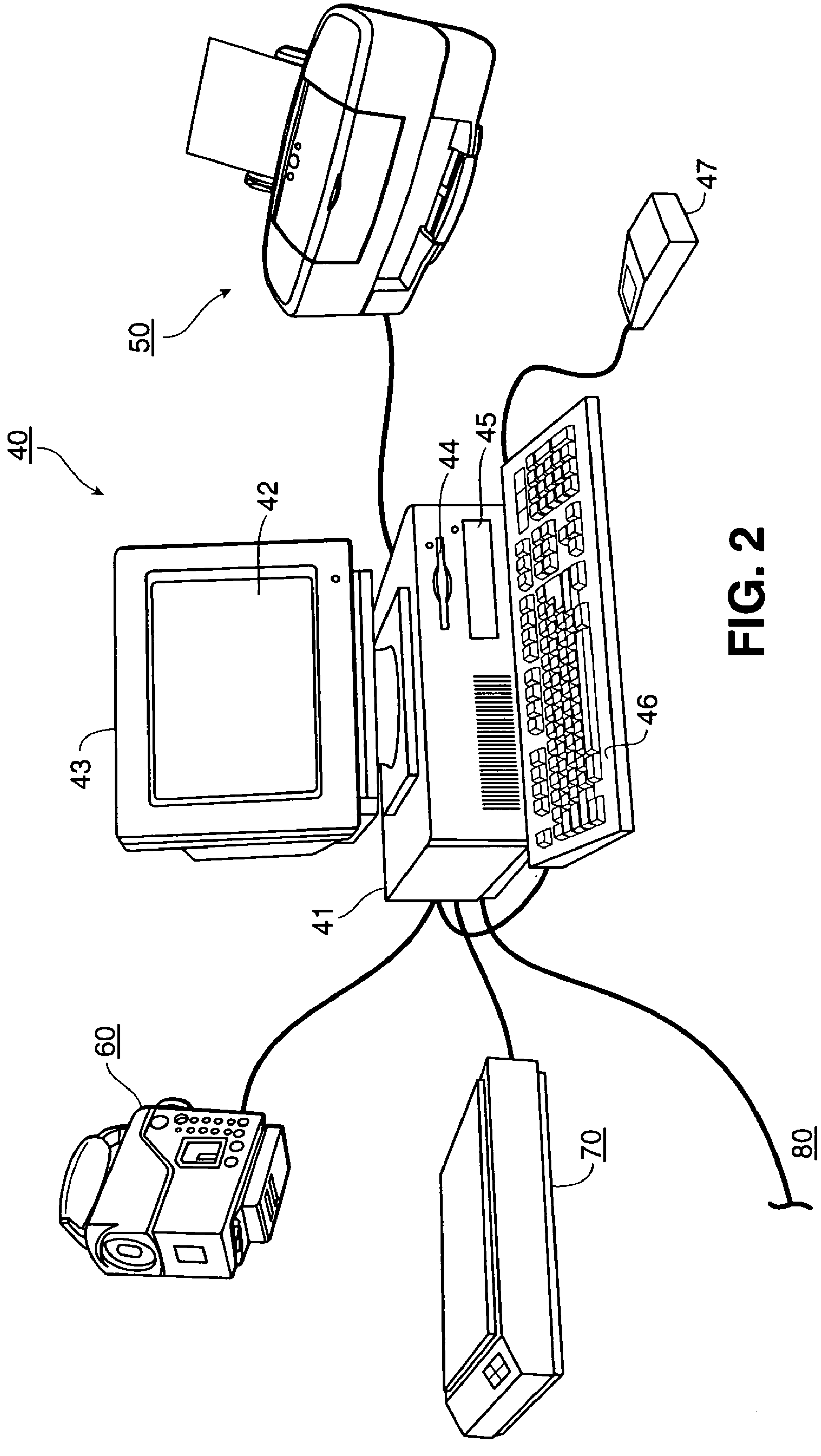


FIG. 2

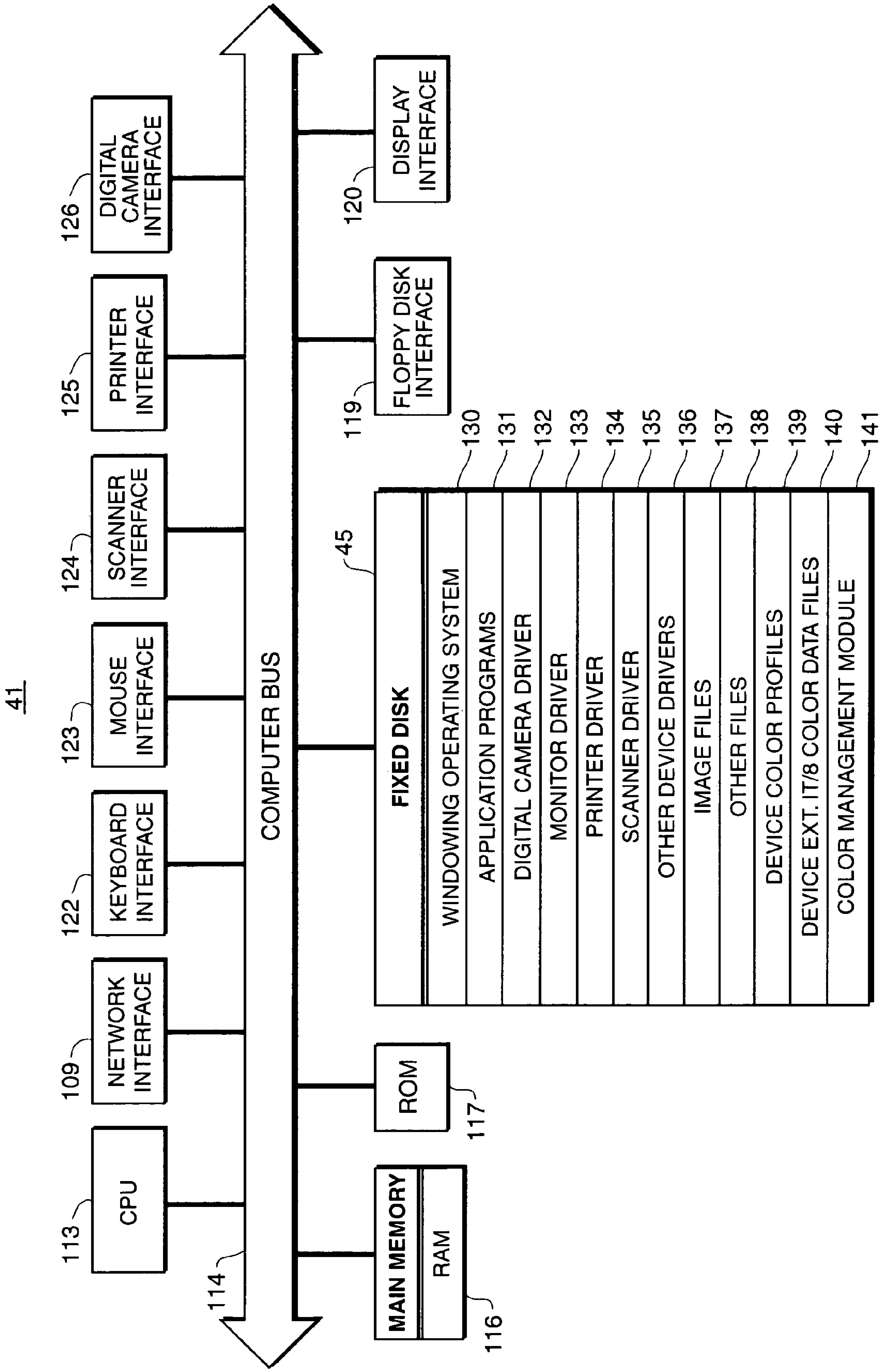

41
CPU
113
NETWORK INTERFACE
109
KEYBOARD INTERFACE
122
MOUSE INTERFACE
123
SCANNER INTERFACE
124
PRINTER INTERFACE
125
DIGITAL CAMERA INTERFACE
126
COMPUTER BUS
114
MAIN MEMORY
RAM
116
ROM
117
FIXED DISK
45
WINDOWING OPERATING SYSTEM
130
APPLICATION PROGRAMS
131
DIGITAL CAMERA DRIVER
132
MONITOR DRIVER
133
PRINTER DRIVER
134
SCANNER DRIVER
135
OTHER DEVICE DRIVERS
136
IMAGE FILES
137
OTHER FILES
138
DEVICE COLOR PROFILES
139
DEVICE EXT. IT/8 COLOR DATA FILES
140
COLOR MANAGEMENT MODULE
141
FLOPPY DISK INTERFACE
119
DISPLAY INTERFACE
120

FIG. 3

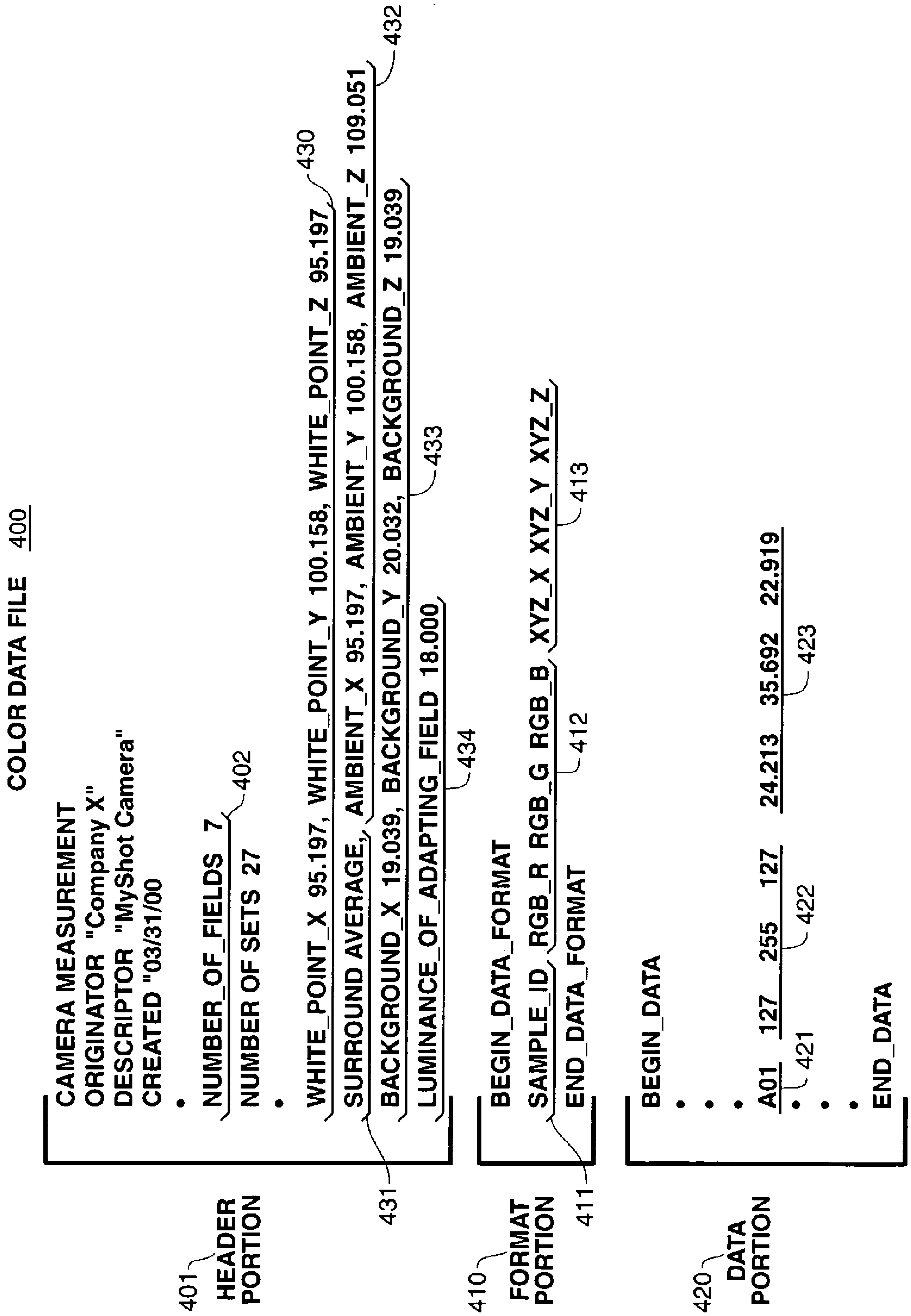

COLOR DATA FILE 400
CAMERA MEASUREMENT
ORIGINATOR "Company X"
DESCRIPTOR "MyShot Camera"
CREATED "03/31/00
NUMBER_OF_FIELDS 7
402
NUMBER OF SETS 27
WHITE_POINT_X 95.197, WHITE_POINT_Y 100.158, WHITE_POINT_Z 95.197
430
SURROUND AVERAGE, AMBIENT_X 95.197, AMBIENT_Y 100.158, AMBIENT_Z 109.051
432
BACKGROUND_X 19.039, BACKGROUND_Y 20.032, BACKGROUND_Z 19.039
433
LUMINANCE_OF_ADAPTING_FIELD 18.000
434
431
401 HEADER PORTION
BEGIN_DATA_FORMAT
SAMPLE_ID RGB_R RGB_G RGB_B XYZ_X XYZ_Y XYZ_Z
412
413
END_DATA_FORMAT
411
410 FORMAT PORTION
BEGIN_DATA
A01 127 255 127 24.213 35.692 22.919
421
422
423
END_DATA
420 DATA PORTION

FIG. 4

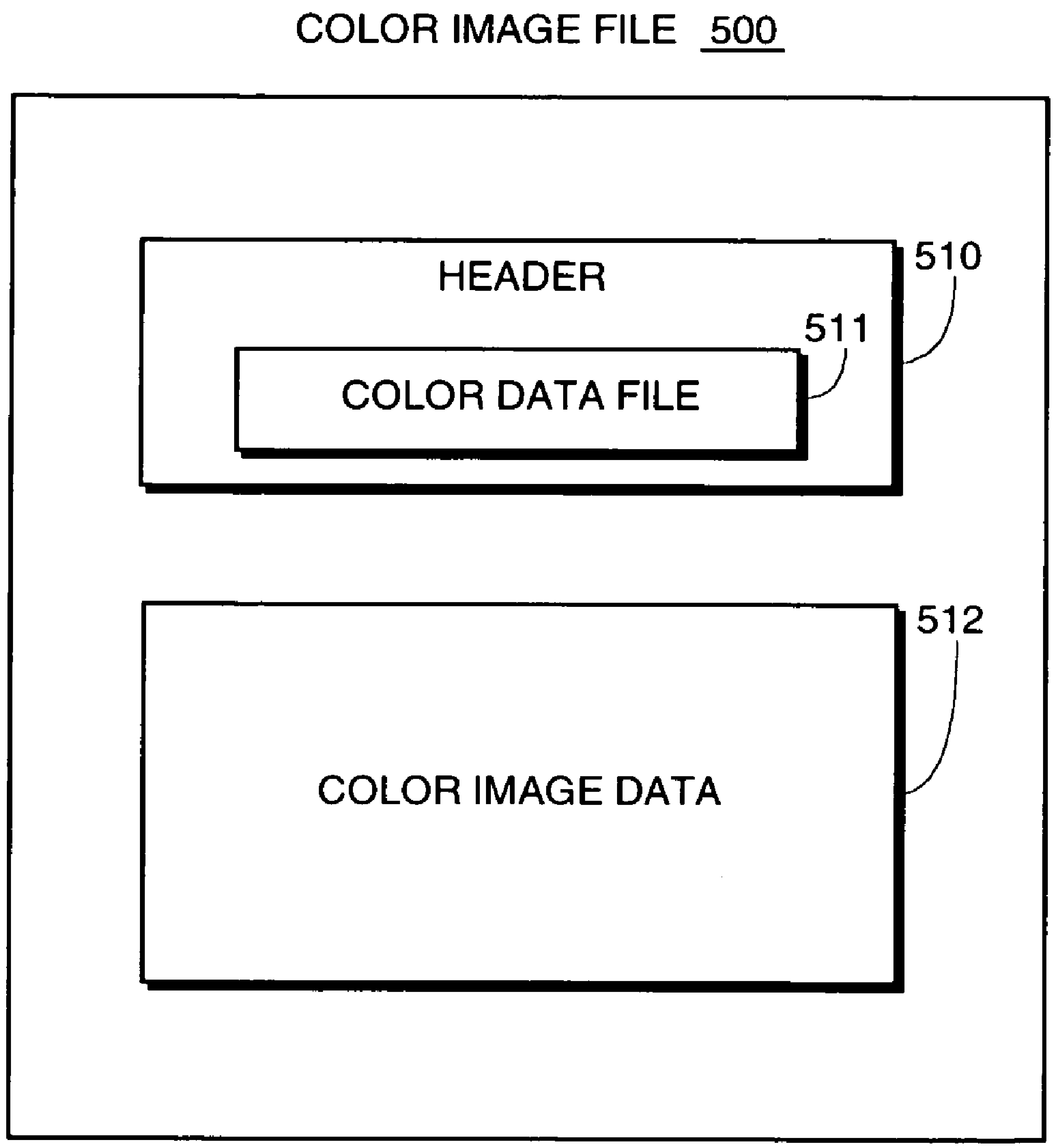

COLOR IMAGE FILE 500
HEADER
510
511
COLOR DATA FILE
512
COLOR IMAGE DATA

FIG. 5

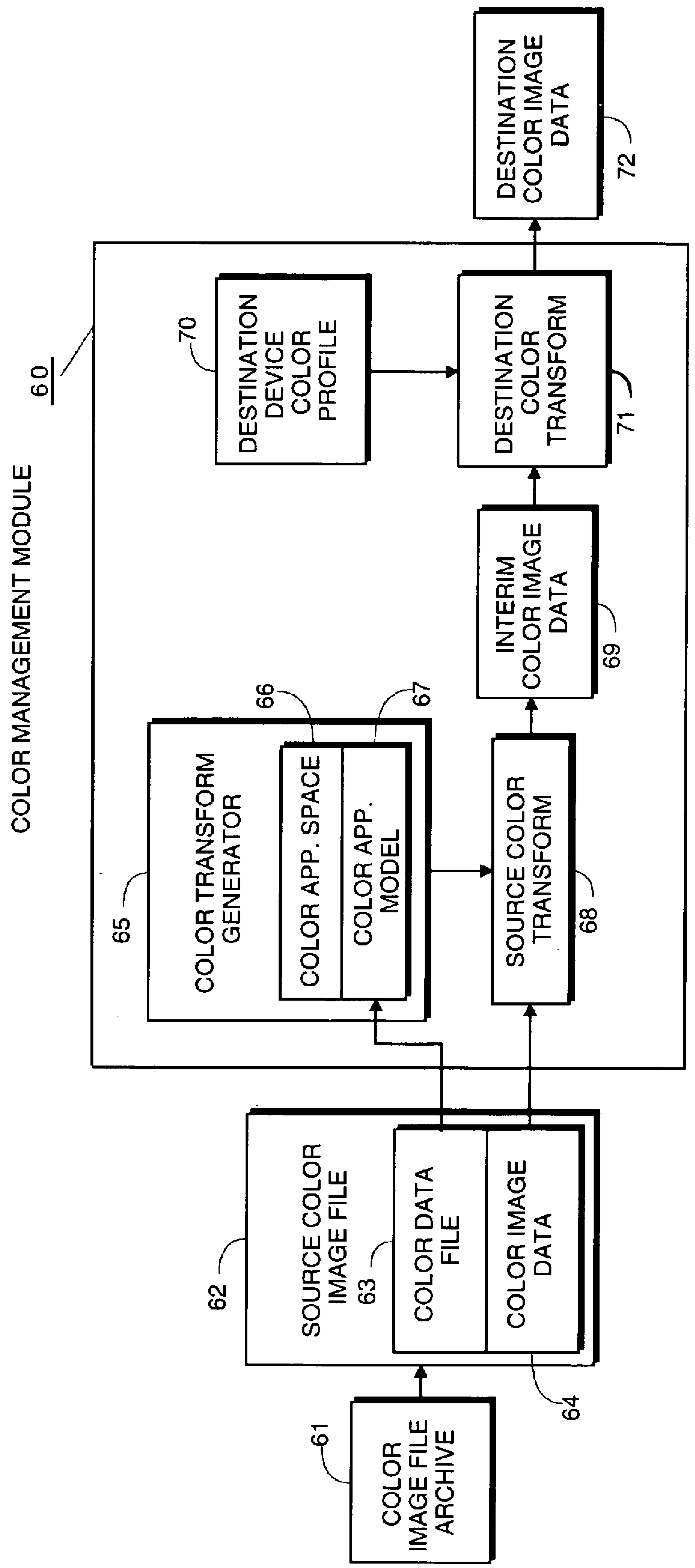

COLOR MANAGEMENT MODULE
60
COLOR IMAGE FILE ARCHIVE
61
SOURCE COLOR IMAGE FILE
62
COLOR DATA FILE
63
COLOR IMAGE DATA
64
COLOR TRANSFORM GENERATOR
65
COLOR APP. SPACE
66
COLOR APP. MODEL
67
SOURCE COLOR TRANSFORM
68
INTERIM COLOR IMAGE DATA
69
DESTINATION DEVICE COLOR PROFILE
70
DESTINATION COLOR TRANSFORM
71
DESTINATION COLOR IMAGE DATA
72

FIG. 6

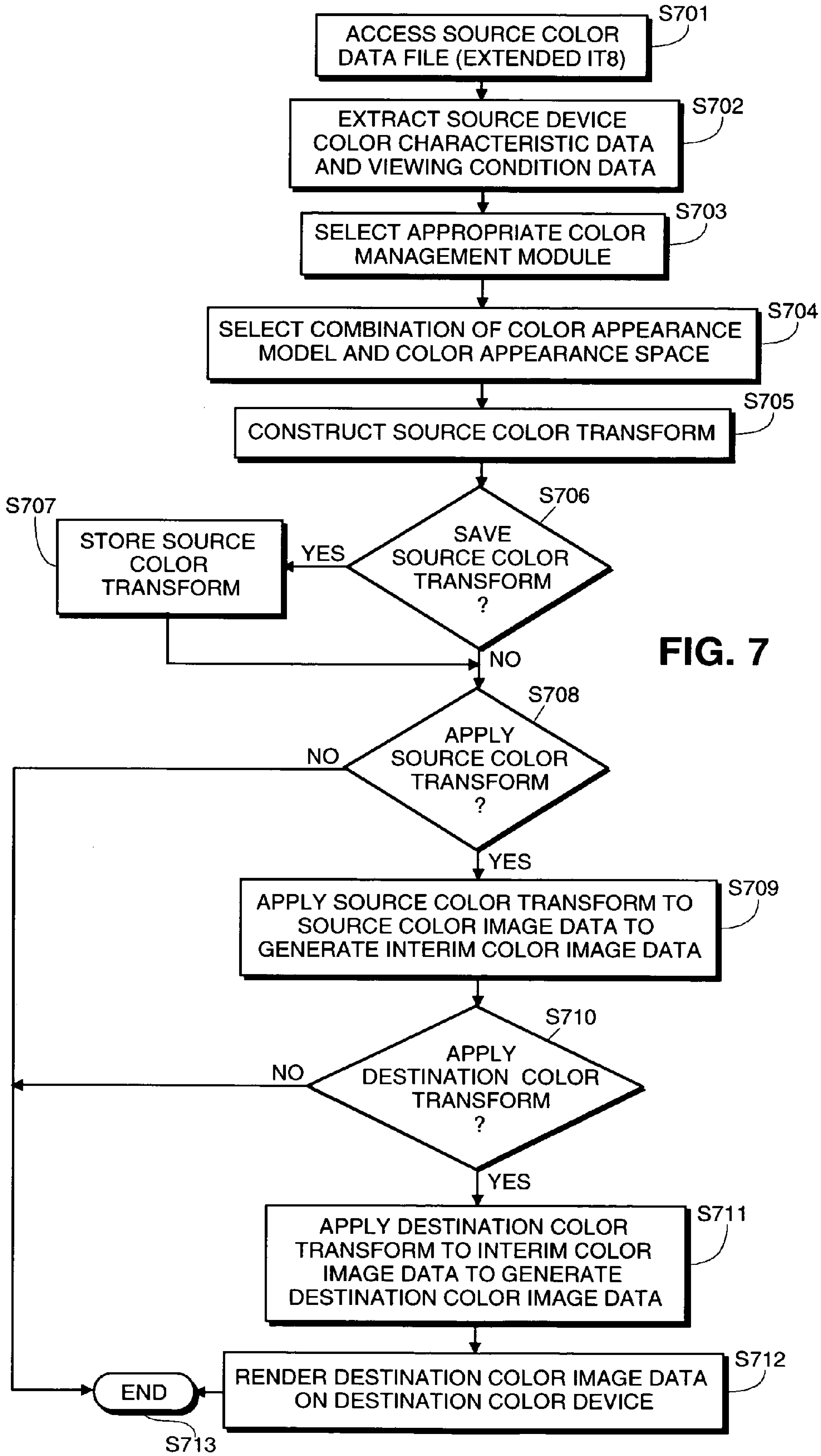

ACCESS SOURCE COLOR DATA FILE (EXTENDED IT8)
S701
EXTRACT SOURCE DEVICE COLOR CHARACTERISTIC DATA AND VIEWING CONDITION DATA
S702
SELECT APPROPRIATE COLOR MANAGEMENT MODULE
S703
SELECT COMBINATION OF COLOR APPEARANCE MODEL AND COLOR APPEARANCE SPACE
S704
CONSTRUCT SOURCE COLOR TRANSFORM
S705
SAVE SOURCE COLOR TRANSFORM ?
S706
YES
STORE SOURCE COLOR TRANSFORM
S707
NO
APPLY SOURCE COLOR TRANSFORM ?
S708
NO
YES
APPLY SOURCE COLOR TRANSFORM TO SOURCE COLOR IMAGE DATA TO GENERATE INTERIM COLOR IMAGE DATA
S709
APPLY DESTINATION COLOR TRANSFORM ?
S710
NO
YES
APPLY DESTINATION COLOR TRANSFORM TO INTERIM COLOR IMAGE DATA TO GENERATE DESTINATION COLOR IMAGE DATA
S711
RENDER DESTINATION COLOR IMAGE DATA ON DESTINATION COLOR DEVICE
S712
END
S713

FIG. 7

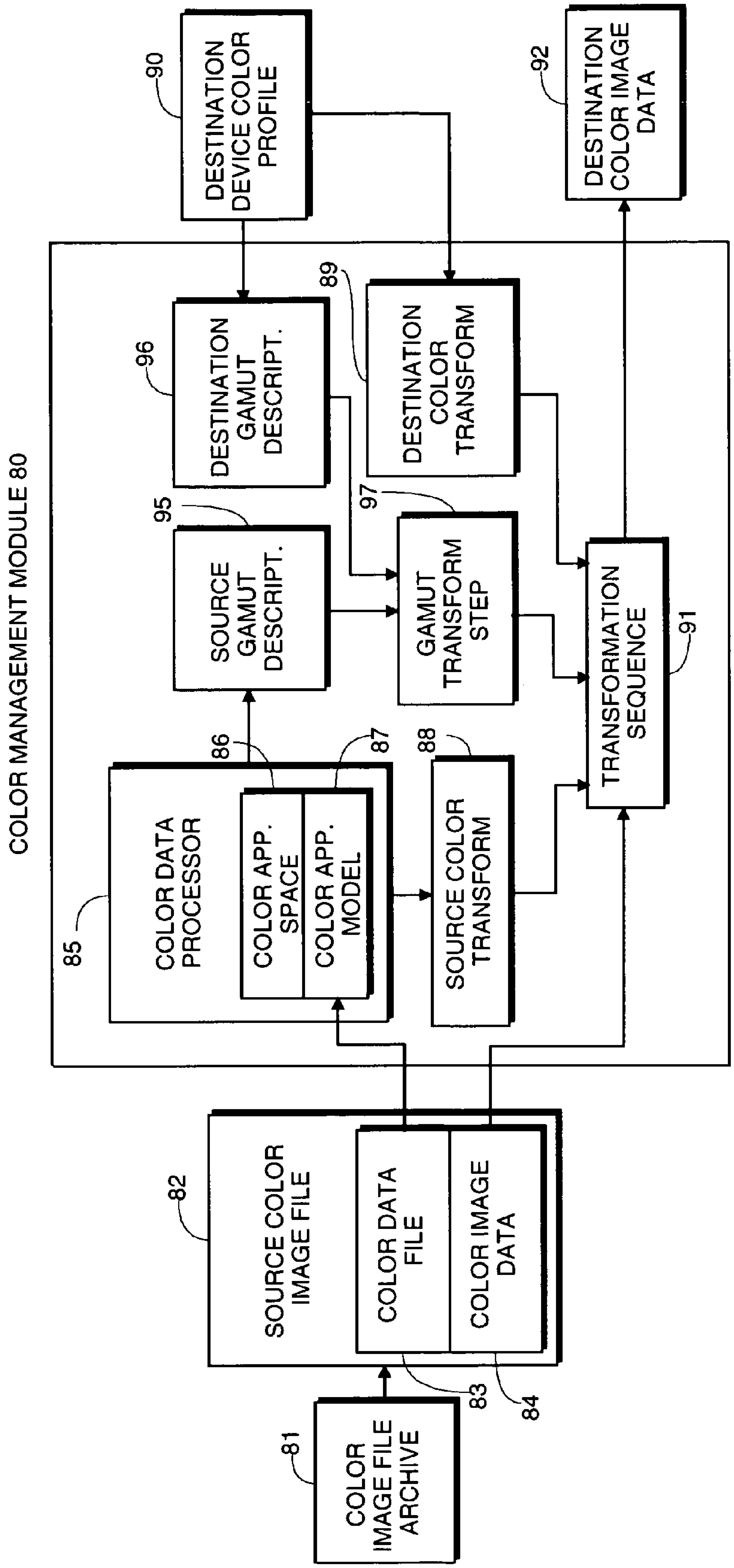

COLOR MANAGEMENT MODULE 80
COLOR IMAGE FILE ARCHIVE
81
SOURCE COLOR IMAGE FILE
82
COLOR DATA FILE
83
COLOR IMAGE DATA
84
COLOR DATA PROCESSOR
85
COLOR APP. SPACE
86
COLOR APP. MODEL
87
SOURCE COLOR TRANSFORM
88
SOURCE GAMUT DESCRIPT.
95
GAMUT TRANSFORM STEP
97
DESTINATION GAMUT DESCRIPT.
96
DESTINATION COLOR TRANSFORM
89
TRANSFORMATION SEQUENCE
91
DESTINATION DEVICE COLOR PROFILE
90
DESTINATION COLOR IMAGE DATA
92

FIG. 8

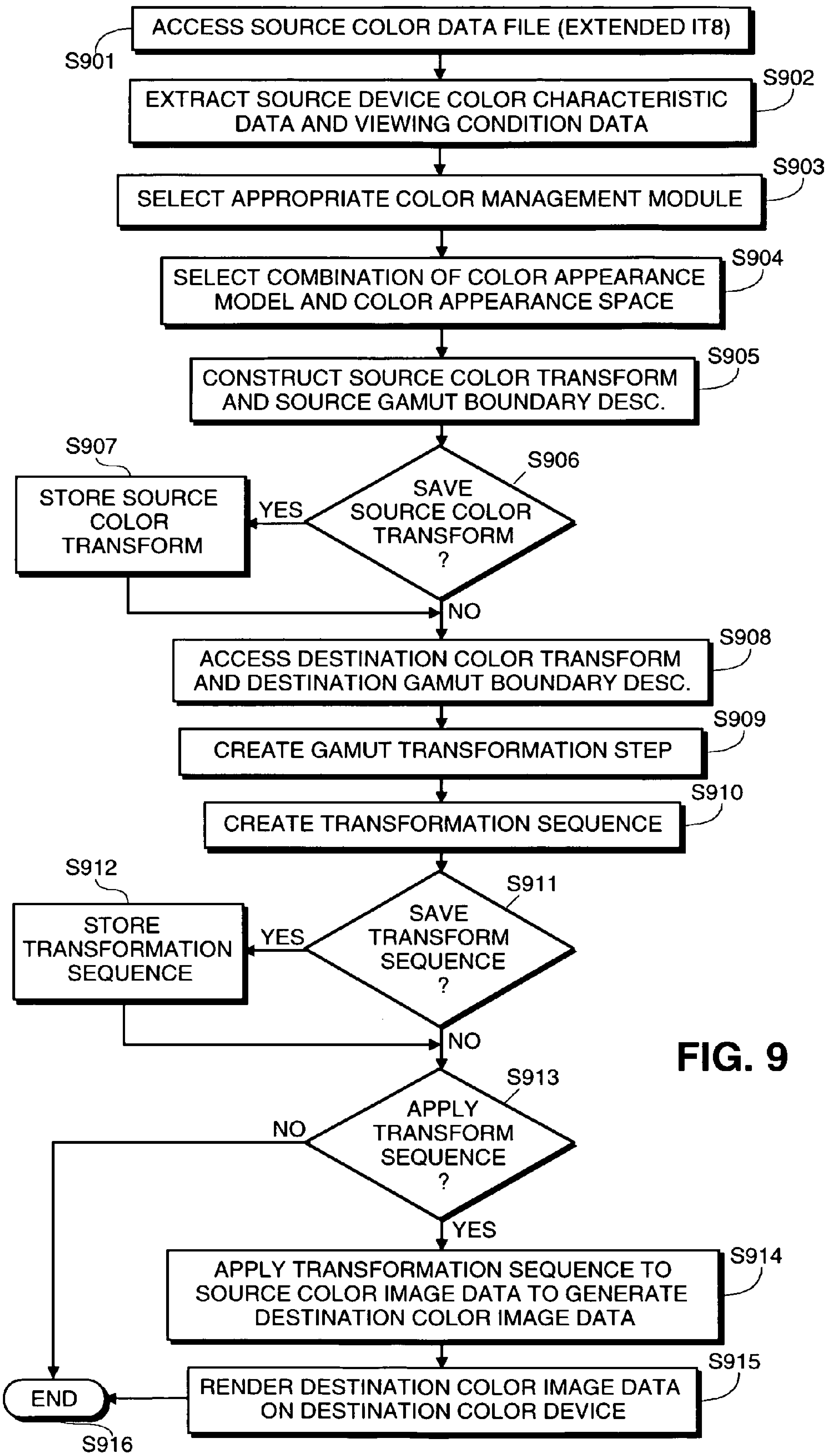

ACCESS SOURCE COLOR DATA FILE (EXTENDED IT8)
S901
EXTRACT SOURCE DEVICE COLOR CHARACTERISTIC DATA AND VIEWING CONDITION DATA
S902
SELECT APPROPRIATE COLOR MANAGEMENT MODULE
S903
SELECT COMBINATION OF COLOR APPEARANCE MODEL AND COLOR APPEARANCE SPACE
S904
CONSTRUCT SOURCE COLOR TRANSFORM AND SOURCE GAMUT BOUNDARY DESC.
S905
SAVE SOURCE COLOR TRANSFORM ?
S906
YES
STORE SOURCE COLOR TRANSFORM
S907
NO
ACCESS DESTINATION COLOR TRANSFORM AND DESTINATION GAMUT BOUNDARY DESC.
S908
CREATE GAMUT TRANSFORMATION STEP
S909
CREATE TRANSFORMATION SEQUENCE
S910
SAVE TRANSFORM SEQUENCE ?
S911
YES
STORE TRANSFORMATION SEQUENCE
S912
NO
APPLY TRANSFORM SEQUENCE ?
S913
NO
YES
APPLY TRANSFORMATION SEQUENCE TO SOURCE COLOR IMAGE DATA TO GENERATE DESTINATION COLOR IMAGE DATA
S914
RENDER DESTINATION COLOR IMAGE DATA ON DESTINATION COLOR DEVICE
S915
END
S916

FIG. 9

COLOR MANAGEMENT SYSTEM USING MEASURED DEVICE DATA

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a color management system for transforming color data, wherein the color management system utilizes measured calorimetric data and viewing condition data corresponding to a source device for generating appropriate color transforms for use in a color transformation sequence to transform color image data into a destination device color space. In this manner, a color transform corresponding to the source device is not generated until it is required by a color management system for transforming color image data into a destination device color space.

2. Incorporation by Reference

Commonly-owned U.S. patent application Ser. No. 09/538,947, entitled "Standardized Device Characterization," by John S. Haikin, is incorporated herein by reference.

3. Description of the Related Art

Typically, color management systems provide a means for representing a color image that was produced by a source device on a destination device. The color characteristics of the source device and the destination device for rendering colors is usually different because the devices use different colorants to render the colors, such as a printer and a monitor, or are of different manufacturers such that colors are rendered according to different techniques. To accommodate the different color characteristics of the two different devices, a color management system is typically used to modify the color image data from the source device so that it can be rendered on the destination device so as to produce a color image which appears similar in nature as the color image rendered by the source device.

Many currently-used color management systems, such as those that support the International Color Consortium (ICC) specifications, use data files known as "device color profiles" to store information which reflects the color characteristics corresponding to a specific device. FIG. **1** depicts a device color profile **1** typically used in conventional color management systems. Specifically, the color characteristic information is provided in color transform **2** which reflects the color characteristics of the source device in relation to a standard, device-independent color space. The color transform can then be used to transform color image data from the source device color space into the device-independent color space as a first step in a comprehensive transformation sequence to ultimately generate color image data in destination device color space for rendering by the destination device. Color profile **1** also includes gamut boundary descriptor **3** which describes the gamut boundary of the device.

The color transform of a color profile corresponding to a particular device is typically in the form of color transformation data which is generated by a profile-building program. It should be noted that there are several different types of profile-building programs for generating color transformation data. A profile-building program constructs the color transformation data for a particular device from corresponding sets of input color value data and output color value data in conjunction with data reflecting expected viewing conditions. The corresponding sets of input color value data and output color value data reflect the color rendering characteristics of the device in relation to a standard, device-independent color space. The many different profile-building programs currently in use often utilize different methods and techniques to generate color transformation data, some of which are proprietary. For example, a profile-building program may incorporate a technique for generating color transformation data which produces the best result for a particular device or a particular type of image as determined by the manufacturer or developer of the profile-building program.

The color transformation data built by the profile-building program is then used to transform color data values from a source device color space to a particular, device-independent color space, and visa versa. Therefore, the construction of a color transform involves the selection of a particular color space and a color appearance model. Currently, there are several standard color spaces and color appearance models from which to select. In addition, the specifications for currently known, standard color spaces and color appearance models are in a state of rapid evolution. As a result, there currently exists a great number of profile-building programs for generating color transformation data based on different combinations of standard color spaces and color appearance models; and the number is rapidly increasing. In addition to the different choices of color spaces and color appearance models, there are many different ways to represent color transformation data in a device profile. For example, the color transformation data may be represented in a color look-up table, a polynomial function, or a sequence of single- and/or multi-variate transforms of arbitrary complexity.

To further complicate matters, many color management systems are designed to reduce processing overhead during the transformation of color image data by optimizing the color transformation data in order to increase the speed of the transformation process. The color transformation data is commonly optimized by eliminating a certain amount of unnecessary and/or less important color data as determined by the developer of the profile-building program. In addition, special proprietary functionality may be implemented into the profile-building program in order to provide more accurate color transformation from a source device color space to a destination device color space in order to achieve a preferred reproduction of the color image on the destination device. Therefore, it can be appreciated that the color transformation data contained in device color profiles corresponding to two separate devices may be quite different even though the two devices are very similar in nature, due to the use of two uniquely different profile-building programs to generate the color transformation data contained in each device color profile.

Device color profiles are typically structured in a standardized format in order to allow many different color management systems to use color profiles which were built by many different profile-building programs. The ICC has defined and standardized a color profile format in order to allow for the efficient interchange of color images from one device to another via color management systems. The ICC color profile format, however, is based on the assumption that the originator of the color image data in the source device knows what the best appearance of that color image data on a destination device should be, regardless of the actual destination device subsequently used to render the color image. This assumption is made because the ICC color profile format contains color transformation data which assumes a particular, standard color space and a particular appearance model for mapping (transforming) the color image data into that color appearance space.

Currently, digital color image data is widely used in computer and networked computing environments, and the use of such color image data is growing rapidly. Color image data corresponding to color images are often archived or placed into stock photography banks for subsequent access and utilization by other users. The use of such color image data by a subsequent user can present significant problems when the subsequent user attempts to transform the color image data into the color space of a destination device for rendering a preferred reproduction of the color image. In addition, the color image data, which is tagged with an ICC color profile corresponding to the source device, may be accessed from a stock photography bank for use by a subsequent user long after the color image data was created. In such a situation, the source color profile may be many revisions old or, if enough time has gone by, the ICC color profile format may no longer be used by color management systems. In such situations, the color image data is effectively unusable by the subsequent user because the subsequent user's color management system cannot interpret the source color profile for use in a transformation sequence. Even if the source color profile can be subsequently used by a color management system, the color transformation data in the color profile may have been based on a standard color space or a color appearance model that is either incompatible or sub-optimal when used in conjunction with color transformation data from the color profile of the destination device.

In addition to the above problems, the representation of the color transformation data in the source device color profile may have been implemented in a particular manner, such as a three-dimensional color look-up table, which is not sufficiently accurate to generate an optimal color transformation sequence. Moreover, even if the source device color profile associated with the color image data and the destination device color profile are fully compatible, a subsequent user of the color image data may wish to generate a different, preferred appearance of the color image, often referred to as a preferred reproduction. Such a preferred reproduction is typically not possible, or is very difficult, when using conventional color profiles because a source device color profile corresponding to the color image data incorporates a particular color space and a particular color appearance model in the color transform.

SUMMARY OF THE INVENTION

The present invention addresses the foregoing problems by providing a color management system for transforming source color image data, wherein the color management system directly accesses and utilizes a source device color data file containing source device color characteristic data and viewing condition data and then constructs an appropriate source color transform for use in a color transformation sequence to transform source color image data into a destination device color space.

According to one embodiment of the invention, a color management system is provided to transform source color image data from a source device into destination color image data for rendering by a destination device. A source color data file corresponding to the source device is accessed, the source color data file containing source device color characteristic data, a source color transform is constructed based on the source device color characteristic data contained in the source color data file, and the source color transform is applied to the source color image data to transform the source color image data from a source device color space into interim color image data in an interim color space.

Preferably, the source color data file is in a predetermined format having tags corresponding to the source device color characteristic data. A set of viewing condition data is preferably also included in corresponding tags of the source color data file. The source color transform is preferably either applied directly to the source color image data or incorporated into a color transformation sequence for application to the source color image data. Preferably, the source device color characteristic data contains measured calorimetric data and corresponding device signal data. In the alternative, the source device color characteristic data represents spectral measurement data corresponding to the source device.

By virtue of this arrangement, a color management system is provided whereby raw calorimetric measurement and device signal data corresponding to a source device is stored in a standardized, formatted color data file for subsequent use by a color management system to generate a source device color transform. In this manner, the color management system is not forced to use a color transform that was originally created when the color image data was generated by the source device. A subsequent user of the color image data is therefore free to use a color management system having a preferred combination of a color space, a color appearance model and a desired set of viewing conditions in order to create a source device color transform. Accordingly, a source device color transform does not have to be created until the color image data is subsequently accessed for use by a subsequent user. In this manner, a set of color image data is associated with a corresponding source color data file that contains color characteristic data of the source device in a well recognized, robust format for use by a variety of current, and not yet known, color management systems.

According to another embodiment of the invention, a color management system is provided for managing color data to transform source color image data from a source device into destination color image data for rendering by a destination device. A source color data file corresponding to the source device is accessed, the source color data file being formatted according to a standard predetermined format and having a plurality of tags containing source device color characteristic data and a set of viewing condition data corresponding to a set of viewing conditions in which the source device color characteristic data was measured. A source color transform is constructed based on the source device color characteristic data and the set of viewing condition data by utilizing an interim color space and a color appearance model, the source color transform for transforming the source color image data from a source device color space into an interim color space. The source color transform is incorporated in a color transformation sequence which is applied to the source color image data to transform the source color image data from the source device color space into a destination device color space.

Preferably, the source color data file is in a predetermined format having tags corresponding to the source device color characteristic data. A set of viewing condition data is preferably also included in corresponding tags of the source color data file. The source color transform is preferably either applied directly to the source color image data or incorporated into a color transformation sequence for application to the source color image data. Preferably, the source device color characteristic data contains measured calorimetric data and corresponding device signal data. In the alternative, the source device color characteristic data contains spectral measurement data corresponding to the source device.

By virtue of this arrangement, a color management system is provided whereby raw calorimetric measurement and device signal data corresponding to a source device is stored in a standardized, formatted color data file for subsequent use by a color management system to generate a source device color transform. In this manner, the color management system is not forced to use a color transform that was originally created when the color image data was generated by the source device. A subsequent user of the color image data is therefore free to use a color management system having a preferred combination of a color space, a color appearance model and a desired set of viewing conditions in order to create a source device color transform. Accordingly, a source device color transform does not have to be created until the color image data is subsequently accessed for use by a subsequent user. In this manner, color image data is identified with a corresponding source color data file that contains color characteristic data of the source device in a well recognized, robust format for use by a variety of current, and not yet known, color management systems.

According to yet another embodiment of the invention, a memory is provided for access by a color management system, the color management system for transforming source color image data from a source device into destination color image data for rendering by a destination device. The memory includes a colorimetric data structure stored in the memory, the calorimetric data structure being formatted according to a predetermined format and containing a set of device color characteristic data elements representing a set of color characteristics of a color device and a set of viewing condition data elements representing a set of viewing conditions of a color device.

Preferably, the calorimetric data structure is in a predetermined format having tags corresponding to the device color characteristic data elements. A set of tags corresponding to the viewing condition data elements is preferably also included. Preferably, the device color characteristic data elements are represented in CIE XYZ color space or a linear transform thereof. In the alternative, the device color characteristic data elements contain spectral measurement data elements representing spectral measurement values corresponding to a color device. The memory having the calorimetric data structure is preferably in the form of a computer-readable medium such as a hard disk, floppy disk, CD-ROM or a file in a file server which is accessible via the internet.

By virtue of this arrangement, raw calorimetric measurement data corresponding to a color device is stored in a standardized, formatted color data file for subsequent use by a color management system to generate a source device color transform. In this manner, a color management system is not forced to use a color transform that was originally created when the color image data was generated in the source device. A subsequent user of the color image data is therefore free to use a color management system having a preferred combination of a color space, a color appearance model and a set of desired viewing conditions in order to create a source device color transform. The aforementioned features provide subsequent users with the ability to control the type of source color transform used in transforming the color image data into another color space. Furthermore, a set of color image data is associated with a corresponding color data file that contains color characteristic data of the source device in a well recognized, robust format for use by a variety of current, and not yet known, color management systems.

Another embodiment of the present invention provides a memory for access by a color management system, the color management system for transforming source color image data from a source device into destination color image data for rendering by a destination device. The memory includes a set of source color image data stored in the memory, and a colorimetric data structure stored in the memory, the calorimetric data structure formatted according to an extended CGATS/IT8 format including a set of tags corresponding to a set of device color characteristic data elements representing a set of measured color characteristics of the source device, and including a set of tags corresponding to a set of viewing condition data elements representing a set of viewing conditions in which the device color characteristic data elements were measured.

Preferably, the device color characteristic data elements are represented in CIE XYZ color space or a linear transform thereof. In the alternative, the device color characteristic data elements contain spectral measurement data elements representing spectral measurement values corresponding to the source device. The memory having the colorimetric data structure is preferably in the form of a computer-readable medium such as a hard disk, floppy disk, CD-ROM or a file in a file server which is accessible via the internet.

By virtue of this arrangement, raw colorimetric measurement data corresponding to a color device is stored in a standardized, formatted color data file for subsequent use by a color management system to generate a source device color transform. In this manner, a color management system is not forced to use a color transform that was originally created when the color image data was generated in the source device. A subsequent user of the color image data is therefore free to use a color management system having a preferred combination of a color space, a color appearance model and a set of desired viewing conditions in order to create a source device color transform. The aforementioned features provide subsequent users with the ability to control the type of source color transform used in transforming the color image data into another color space. Furthermore, a set of color image data is associated with a corresponding color data file that contains color characteristic data of the source device in a well recognized, robust format for use by a variety of current, and not yet known, color management systems.

This brief summary has been provided so that the nature of the invention may be understood quickly. A more complete understanding of the invention can be obtained by reference to the following detailed description of the preferred embodiment thereof in connection with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram for explaining a typical device color profile used in conventional color management systems.

FIG. **2** is a representative view of a networked computer system in which the present invention may be implemented.

FIG. **3** is a detailed block diagram for providing an explanation of the internal architecture of the computer equipment shown in the computer system of FIG. **1**.

FIG. **4** is a view for illustrating a color data file according to one embodiment of the present invention.

FIG. **5** is a detailed block diagram for providing an explanation of an embedded color data file according to one embodiment of the present invention.

FIG. **6** is a detailed block diagram for providing an explanation of a color management system according to one embodiment of the present invention.

FIG. **7** is a flowchart for providing a detailed explanation of the color management system shown in FIG. **6**.

FIG. **8** is a detailed block diagram for providing an explanation of a color management system according to another embodiment of the present invention.

FIG. **9** is a flowchart for providing a detailed explanation of the color management system shown in FIG. **8**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is generally directed to a color management system for transforming source color image data, wherein the color management system directly accesses and utilizes a source device color data file containing source device color characteristic data and viewing condition data and then constructs an appropriate source color transform for use in a color transformation sequence to transform source color image data into a destination device color space. In this manner, source color image data can be archived and an associated source color transform is not constructed until it is subsequently needed by a color management system for transforming the source color image data into a destination device color space. A subsequent user of the archived source color image data can thereby select and/or control the type of color management system used to construct the source color transform based upon a desired combination of a color appearance space, a color appearance model and a desired set of viewing conditions. The present invention may be implemented in an output device driver, such as a printer driver contained in a computing device, or the present invention may be implemented in a color management software application module for use in a general purpose computer. It can be appreciated that the present invention is not limited to the aforementioned embodiments and that the present invention may be implemented in other forms as well.

FIG. **2** is a view showing the external appearance of a representative computing system including computing equipment, peripherals and digital devices which may be used in connection with the practice of the present invention. Computing equipment **40** includes host processor **41** which comprises a personal computer (hereinafter "PC"), preferably an IBM PC-compatible computer having a windowing environment such as Microsoft Windows 2000, Windows NT, Windows 98 or Windows 95, although it may be a Macintosh or a non-windows-based computer. Provided with computing equipment **40** are color monitor **43** including display screen **42**, keyboard **46** for entering text data and user commands, and pointing device **47**. Pointing device **47** preferably comprises a mouse for pointing and for manipulating objects displayed on display screen **42**.

Computing equipment **40** includes a computer-readable memory medium such as computer fixed disk **45** and/or floppy disk drive **44**. Floppy disk drive **44** provides a means whereby computing equipment **40** can access information, such as image data, computer-executable process steps, application programs, etc. stored on removable memory media. A similar CD-ROM interface (not shown) may be provided for computing equipment **40** through which computing equipment **40** can access information stored on removable CD-ROM media.

Printer **50** is a printer, preferably a color bubble jet printer, which forms color images on a recording medium such as paper or transparencies or the like. The invention is usable with other printers, however, so long as the printer is capable of being interfaced to computing equipment **40**. In addition, digital color scanner **70** is provided for scanning documents and images into computing equipment **40** and digital color camera **60** is provided for sending digital images to computing equipment **40**. Of course, computing equipment **40** may acquire digital image data from other sources such as a digital video camera or from a local area network or the Internet via network interface bus **80**.

FIG. **3** is a detailed block diagram showing the internal architecture of host processor **41** of computing equipment **40**. As shown in FIG. **3**, host processor **41** includes central processing unit (CPU) **113** which interfaces with computer bus **114**. Also interfacing with computer bus **114** are fixed disk **45**, network interface **109**, random access memory (RAM) **116** for use as main memory, read only memory (ROM) **117**, floppy disk interface **119**, display interface **120** to monitor **43**, keyboard interface **122** to keyboard **46**, mouse interface **123** to pointing device **47**, scanner interface **124** to scanner **70**, printer interface **125** to printer **50**, and digital camera interface **126** to digital camera **60**.

Main memory **116** interfaces with computer bus **114** so as to provide RAM storage to CPU **113** during execution of software programs such as an operating system, application programs and device drivers. More specifically, CPU **113** loads computer-executable process steps from fixed disk **45**, another storage device, or some other source such as a network, into a region of main memory **116**. CPU **113** then executes the stored process steps from main memory **116** in order to execute software programs such as an operating system, application programs and device drivers. Data such as color images can be stored in main memory **116**, where the data can be accessed by CPU **113** during the execution of computer-executable process steps which use or alter the data.

As also shown in FIG. **3**, fixed disk **45** contains operating system **130**, which is preferably a windowing operating system although other operating systems may be used, application programs **131**, such as image processing applications that include a color management module, and plural device drivers, including a digital camera driver **132**, monitor driver **133**, printer driver **134**, scanner driver **135**, and other device drivers **136**. Fixed disk **45** also includes image files **137**, other files **138**, device color profiles **139**, which are discussed in more detail below, device extended IT8 color data files **140**, which are also discussed in more detail below, and color management module **141** in which the present invention may be implemented. The functions of color management module **141** are preferably provided in the form of computer-executable process steps. As mentioned above, the functions of color management module **141** may be alternatively integrated into an output device driver, such as printer driver **134**, or into an application program for performing processing of color image data, such as one of application programs **131**.

FIG. **4** is a view for illustrating one embodiment of a color data file according to the present invention. In contrast to the device color profile of FIG. **1**, the color data file depicted in FIG. **4** contains raw color characteristic data and viewing condition data corresponding to a color device. In this manner, a subsequent user of an archived color image is not forced to use a previously-generated color transform corresponding to the source device that created the archived color image. Instead, the color data file of the present invention allows a subsequent user of the archived color image to select and use a color management system having a preferred combination of a color space, a color appearance model and a set of desired viewing conditions in order to create a source device color transform for use in transforming the archived color image data into the color space of a particular destination device.

The color data file of the present invention is preferably a formatted file containing tags for the various data elements included therein, including tags for the raw color characteristic data and viewing condition data corresponding to a color device. Currently, a standardized data file format, known as CGATS/IT8, exists for storing color characteristic data corresponding to a color device. The CGATS/IT8 standard includes tags for storing measured calorimetric data corresponding to a color device. For example, the CGATS/IT8 format can be used in a colorimetric measurement scenario in which an array of color patches generated by a color device is measured and the measured calorimetric data corresponding to each color patch is stored in a color data file having the CGATS/IT8 format. In this manner, the colorimetric data is stored in a standardized fashion for future reference and use.

None of the CGATS/IT8 standards provide tags for containing both device control signals of the color device and corresponding measured colorimetric data. For example, it is often desirable to correlate a set of printer input signals to a set of calorimetric data measured from the rendered color image that was generated in response to the printer input signals. These correlated sets of data can then be used to generate a color transform for modeling the printer's color characteristics and capabilities. In this regard, commonly-owned U.S. patent application Ser. No. 09/538,947, entitled "Standardized Device Characterization," by John S. Haikin, provides an extended CGATS/IT8 format standard which includes tags for containing device control signals of a color device, in addition to the other extensions described therein. In a similar manner, the present invention utilizes extensions to the CGATS/IT8 format including tags for device control signal data as well as tags for viewing condition data. In this manner, the extended CGATS/IT8 format of the present invention contains color characteristic data and viewing condition data corresponding to a color device for use in the subsequent creation of a color transform corresponding to the color device.

Turning to FIG. **4**, a color data file corresponding to the present invention is depicted. It can be seen from FIG. **4** that color data file **400** is organized in a formatted fashion corresponding to a predetermined format so as to include header portion **401**, format portion **410** and data portion **420**. Header portion **401** includes a format descriptor to describe the format of color data file **400**, which in this example is a format for camera color characteristic data. An indication of the originator of the data contained in color data file **400** is also included as well as a descriptor for describing the data contained therein. Header Portion **401** also includes a creation date.

Header Portion **401** further includes NUMBER_OF_FIELDS **402** which indicates the different types of data provided in color data file **400** corresponding to each particular color measurement. In this case, NUMBER_OF_FIELDS **402** has a value of 7 corresponding to the fields for SAMPLE_ID **411**, RGB data **412**, and XYZ data **413**. As illustrated in Format Portion **410**, SAMPLE_ID **411** is a field for containing an identification of the particular color sample which is being measured. RGB data **412** includes red, green and blue data corresponding to device signals for a particular color device being measured. As discussed above, when measuring calorimetric data for a printer, RGB data **412** represents the three RGB input printer signals for directing the printer to print a color image. XYZ data **413** includes X, Y and Z components of measured calorimetric data corresponding to a color device. As discussed above, when the color characteristics of a printer are being measured, XYZ data **413** represents the three measured color values of the printed color image. In the case of a scanner, RGB data **412** represents output signals from the scanner in response to scanning of a color image, and XYZ data **413** represents the measured calorimetric data of the color image being scanned. In this manner, both input and output color data corresponding to a color device are provided within one file for subsequent access and used to characterize and/or model the color capabilities of the color device.

Header Portion **401** also includes WHITE_POINT data **430**, SURROUND data **431**, AMBIENT data **432**, BACKGROUND data **433** and LUMINANCE_OF_ADAPTING_FIELD data **434** for representing a set of viewing conditions. Preferably, the viewing conditions represent the viewing conditions measured at the time that the device signal data elements, such as RGB data **412**, and the measured calorimetric data elements, such as XYZ data **413**, were recorded. In this manner, the viewing conditions in which the color device was measured can be stored in the same file with the device signal data and measured calorimetric data for future use.

WHITE_POINT data **430** is a white point colorimetric specification corresponding to the viewing condition white point. AMBIENT data **432** is an ambient colorimetric specification corresponding to ambient viewing conditions. SURROUND data **431** corresponds to surround colorimetric specification for representing the remainder of the visual field outside the background surrounding the color sample being measured. BACKGROUND data **433** corresponds to background colorimetric specification for a background of the color sample being measured. The background commonly includes an area immediately adjacent to the point being measured out to approximately 10 degrees. LUMINANCE_OF_ADAPTING_FIELD **434** represents an adapting field colorimetric specification corresponding to the state of adaption of a scene in which the sample point is being measured. Such viewing condition measurements are commonly known in the art of color management. The aforementioned array of viewing conditions enables a subsequent user of color data file to properly use the color characteristic data contained in color data file **400** for constructing a proper characterization of the color device to which color data file **400** corresponds. For example, if color data file **400** corresponds to a printer, then RGB data **412**, XYZ data **413**, and viewing condition data **430** to **434** can be accessed and utilized in order to create a proper color transform for transforming color image data generated by the printer into another color space, such as a profile connection space.

Data portion **420** of color data file **400** is seen to have corresponding data values for each of the aforementioned fields described in Format Portion **410**. Specifically, a row of data in data portion **420** corresponds to a measured color image sample identified as A**01** for SAMPLE_ID **421**. Similarly, device signal data represented by RGB data **412** is provided in RGB values **422**, and measured colorimetric data represented by XYZ data **413** is provided in XYZ data **423**.

In this embodiment, RGB data **412** and XYZ data **413** represent device signal data and measured calorimetric data, respectively. In the alternative, these fields can be used to contain spectral measurement values corresponding to the color device. In addition, viewing condition fields **430** to **434** can be used to represent a desired set of viewing conditions in the case that RGB data **412** and XYZ data **413** contain spectral measurement values. In this manner, color data file **400** has the flexibility to represent color characteristic data of a color device in different forms.

It can be appreciated that color data file **400** can be maintained in a memory area, such as a floppy disk, hard disk, CD-ROM, or a network server for access in a networked computing environment, including the Internet and World Wide Web. Preferably, color data file **400** is embedded in a color image file containing a set of color image data for representing a color image. In this regard, FIG. **5** depicts color image file **500** in which color data file **511** is embedded. In particular, color image file **500** includes header **510** and color image data **512** which corresponds to a color image. Header **510** includes a tag for containing color data file **511**, color data file **511** corresponding to a color data file as depicted in FIG. **4**. In this manner, color data file **511** corresponds to the source color device, such as a digital camera or scanner, which generated color image data **512**. Color image file **500** therefore provides a convenient package for combining color image data **512** with the color characteristic and viewing condition data corresponding to the source color device which generated color image data **512**. It can be appreciated that color image file **500** is beneficial for storing and archiving color image data such that, regardless of the amount of time elapsed since the generation of color image data **512**, a subsequent user can access color image file **500** and then access and utilize the color characteristic data and viewing condition data contained in color data file **511** to create an appropriate color transform for use in working with color image data **512**. In this manner, a subsequent user of color image data **512** is not constrained to using an outdated color transform corresponding to color image data **512**, or a color transform which produces sub-optical results with the subsequent user's color management system.

FIG. **6** provides a detailed block diagram for illustrating the use of a color data file according to the present invention in a color management system. Turning to FIG. **6**, it can be seen that source color image file **62** is accessed from color image archive **61** for use by a subsequent user. For example, a graphic artist may browse color image archive **61** and choose source color image file **62** corresponding to a color image that the graphic artist wishes to use in a composition image. Source color image file **62** contains color data file **63** corresponding to a source device as described in FIG. **4** and also contains color image data **64**. In this example, source color image file **62** corresponds to a source device, and color image data **64** is in the RGB color space associated with the source device (digital camera or scanner).

Color management module **60** is then utilized for performing color management of color image data **64** contained in source color image file **62**. Specifically, as discussed above, a subsequent user of source color image file **62** can select and/or control a preferred color management module depending on the color appearance space and color appearance model that the subsequent user wishes to apply to create a source color transform from color data file **63**. As represented in FIG. **6**, color data file **63** is passed to color transform generator **65** which is a function of color management module **60**. Color transform generator **65** utilizes color appearance space **66** and color appearance model **67** in order to construct source color transform **68** based on the source device color characteristic data and viewing condition data contained in color data file **63** as depicted in FIG. **4**.

In particular, device signal data represented by RGB data and measured colorimetric data represented by XYZ data are accessed from color data file **63** for use by color transform generator **65**. In addition, viewing condition data is accessed from color data file **63** for use in conjunction with the device signal data and measured calorimetric data in order to generate source color transform **68** for transforming color image data **64** into color appearance space **66**. In this example, color appearance space **66** is a profile connection space. In addition, color appearance model **67** is used to define the source color transform **68**. Source color transform **68** may be represented in the form of a look-up table, or in other forms, such as a polynomial function, a single-variate transform, or a multi-variate transform. In addition, it can be appreciated that color appearance space **66** can be any one of a number of different types of color appearance spaces such as a CIE Lab color space, or a color space composed of a lightness component, and two orthogonal color components for defining a chroma and a hue, such as Jch and Jab color spaces. The present invention is not limited to the use of the aforementioned color appearance spaces, and it can be appreciated that other color appearance spaces may be used, including other types of device-independent color spaces.

Color transform generator **65** of color management module **60** generates source color transform **68** in accordance with a particular color transform generation method and/or algorithm. It can be appreciated that color management module **60** may implement any one of a different number of color transform generation methods and/or algorithms. Such color transform generation methods and/or algorithms may include one or more optimization functions for optimizing source color transform **68** to enable source color transform **68** to process color image data **64** in a more efficient fashion, to process color image data **64** so as to achieve greater accuracy in the reproduction of color image data **64**, or to process color image data **64** to achieve a particular preferred reproduction of color image data **64**.

Source color transform **68** is then applied to color image data **64** in order to create interim color image data **69**, which in this example is in a profile connection space, thereby allowing interim color image data **69** to be further processed by other color transforms which are also in the profile connection space. Source color transform **68** can also be stored in a memory such as a floppy, hard disk, CD-ROM or the like for subsequent access by a user in order to reduce subsequent processing of color image data **64** or of other color image data files generated from the same source device. In the example illustrated in FIG. **6**, interim color image data **69** is further transformed by destination color transform **71** which was accessed from a typical destination device color profile **70**. It can be appreciated that destination color transform **71** may alternatively be generated by color transform generator **65** if a destination color data file similar to source color data file **63** exists for the particular destination device. In any event, whether destination color transform **71** is accessed from destination device color profile **70** or is generated from color transform generator **65**, interim color image data **69** is transformed into destination color image data **72**. In this example, destination device color profile **70** corresponds to an ink jet printer, and destination color transform **71** therefore transforms the color image data into a CMYK color space. Destination color image data **72** can then be rendered by the destination device, which in this case is a printer.

FIG. **7** is a flowchart for explaining one implementation of the color management system and color data file of the present invention as depicted in FIG. **6**. In step S**701**, the source color data file according to the present invention is accessed, either from a separate memory area or from within a source color image file as depicted in FIG. **6**. In step S**702**, the source device color characteristic data, such as device signal data and measured calorimetric data, is extracted along with the viewing condition data from the source color data file. As previously discussed, the measured calorimetric data is preferably in XYZ color space so as to provide compatibility with both current and future color management systems. An appropriate color management module for managing the color image data to be processed is selected in step S**703**. The color management module can be selected based on a preexisting embedded combination of color appearance space and color appearance model that are desired by a user, or based on the manner in which the color management module constructs a color transform.

Preferably, the color management module allows a user to select from one of many different color appearance spaces and from one of may different color appearance models to create a color transform for optimal color management results (S**704**). In step S**705**, a source color transform is constructed based on the color characteristic data and viewing condition data extracted from the source color data file, in addition to the color appearance space and color appearance model utilized by the color management module. Next, it is determined whether the user wishes to save the generated source color transform for future use (S**706**). If the source color transform is to be saved, it can be stored in a memory area such as a hard disk, floppy, CD-ROM or network server, as discussed above (S**707**), and flow then passes to step S**708**. If the source color transform is not to be saved, flow passes to step S**708** in which it is determined whether or not to apply the source color transform to the source color image data. If the user wishes to apply the source color transform to the source color image data, the source color transform is applied to the source color image data in step S**709** in order to create interim color image data.

As discussed above, the interim color image data is preferably in a profile connection space to facilitate further color management of the interim color image data. If the source color transform is not to be applied to the source color image data, flow passes to step S**713** which is the end of the process. If the interim color image data is generated in step S**709**, flow passes to step S**710** in which it is determined whether to apply a destination color transform on the interim color image data in order to generate destination color image data for rendering by a destination device, such as a printer. If a destination color transform is not to be applied, flow passes to the end in step S**713**. If, however, a destination color transform is to be applied, flow passes to step S**711** in which a destination color transform is applied to the interim color image data, thereby generating destination color image data. As discussed above, a destination color transform may be accessed from a conventional destination device color profile which contains a destination color transform or, in the alternative, a destination color transform may be generated in the same manner as source color transform **68** of FIG. **6**. In such a situation, a destination color data file similar to source color data file **63** is accessed and a destination color transform is generated in a manner similar to that described above with respect to steps S**701** to S**705**. In either case, the destination color transform is applied in order to create destination color image data.

In step S**712**, the destination color image data is passed to the destination device, such as a printer, for rendering of a color image. Flow then passes to the end (step S**713**). In this manner, it can be appreciated that a subsequent user of an archived image file can select an appropriate color management module to construct a source color transform from the color characteristic and viewing condition data contained in the source color data file, thereby achieving preferred and/or optimal color management of the color image data.

FIG. **8** provides a detailed block diagram for illustrating the use of a color data file in a color management system according to another embodiment of the present invention. In this embodiment, the color data file is used to construct a color transform which is incorporated into a comprehensive color transformation sequence for application to color image data. Turning to FIG. **8**, it can be seen that source color image file **82** is accessed from color image archive **81** for use by a user. For example, a graphic artist may browse color image archive **81** and choose source color image file **82** corresponding to a color image that the graphic artist wishes to use in a composition image. Source color image file **82** contains source color data file **83** as described in FIG. **4** and also contains color image data **84**. In this example, source color image file **82** corresponds to a scanner, and color image data **84** is in RGB color space.

Color management module **80** is then utilized for performing color management of color image data **84** contained in source color image file **82**. Specifically, as discussed above, a subsequent user of source color image file **82** can select and/or control a preferred color management module depending on the color appearance space and color appearance model that the subsequent user wishes to apply to create a source color transform from color data file **83**. As represented in FIG. **8**, color data file **83** is passed to color transform generator **85** which is a function of color management module **80**. Color data processor **85** utilizes color appearance space **86** and color appearance model **87** in order to construct source color transform **88** based on the device color characteristic data and viewing condition data contained in color data file **83** as depicted in FIG. **4**.

In particular, device signal data represented by RGB data and measured calorimetric data represented by XYZ data from color data file **83** is accessed for use by color data processor **85**. In addition, viewing condition data is accessed from color data file **83** to be used in conjunction with the device signal data and measured colorimetric data in order to generate source color transform **88** for transforming color image data **84** into color appearance space **86**. In this example, color appearance space **86** is a profile connection space. In addition, color appearance model **87** is used to define source color transform **88**. Source color transform **88** may be represented by a look-up table, and it can be appreciated that source color transform may be provided in other formats, such as a polynomial function, a single-variate transform, or a multi-variate transform. In addition, it can be appreciated that color appearance space **86** can be any one of a number of different types of color appearance spaces such as a CIE Lab color space, or a color space composed of a lightness component, and two orthogonal color components for defining a chroma and a hue, such as Jch and Jab color spaces. The present invention is not limited to the use of the aforementioned color appearance spaces, and it can be appreciated that other color appearance spaces may be used, including other forms of device-independent color spaces.

Color data processor **85** of color management module **80** generates source color transform **88** in accordance with a particular color transform generation method and/or algorithm. It can be appreciated that color management module **80** may implement any one of a different number of color transform generation methods and/or algorithms. Such color transform generation methods and/or algorithms may include one or more optimization functions for optimizing source color transform **88** to enable source color transform **88** to process color image data **84** in a more efficient fashion, to process color image data **84** so as to achieve greater accuracy in the reproduction of color image data **84**, or to process color image data **84** to achieve a particular preferred reproduction of color image data **84**.

Color data processor **85** also generates source gamut description **95** from source color data file **83**. In this manner, source color data file **83** does not need to contain a separate gamut boundary description for the source device. In particular, the device signal data and measured calorimetric data are utilized to generate source gamut boundary description **95**.

It can be appreciated that source color transform **88** can be applied to color image data **84**, as depicted in FIG. **6**; however, source color transform can alternatively be incorporated into a comprehensive color transformation sequence, thereby allowing source color image data **84** to be transformed into destination color image data **92**. Source color transform **88** can be stored in a memory such as a floppy, hard disk, CD-ROM or the like for subsequent access and use. In the example illustrated in FIG. **8**, destination color transform **89** is accessed and utilized in conjunction with source color transform **88** to create transformation sequence **91**. Destination gamut description **96** is also accessed and used in conjunction with source gamut description **95** and a gamut boundary algorithm from color management module **80** to create gamut transform step **97**. Gamut transform step **97** is then incorporated into transformation sequence **91**. Transformation sequence **91** is then applied to color image data **84** to generate destination color image data **92** for rendering on a destination device, such as a printer. As discussed above, destination color transform **89** and destination gamut description **96** can be accessed from a typical destination device color profile **90**. It can be appreciated that destination color transform **91** and destination gamut description **96** may alternatively be generated by color data processor **85** if a destination color data file similar to source color data file **83** exists for the particular destination device. In this example, destination device color profile **90** corresponds to an ink jet printer, and destination color transform **89** is used to transform color data into a CMYK color space.

FIG. **9** is a flowchart for explaining the color management system and color data file according to the embodiment of the present invention as depicted in FIG. **8**. In step S**901**, the source color data file according to the present invention is accessed, either from a separate memory area or from within a source color image file as depicted in FIG. **8**. In step S**902**, the source device color characteristic data, such as device signal data and measured calorimetric data, is extracted, in addition to the viewing condition data, from the source color data file. As previously discussed, the measured colorimetric data is preferably in XYZ color space so as to provide compatibility with both current and future color management systems. An appropriate color management module for managing the color image data to be processed is selected in step S**903**. The color management module can be selected based upon a preexisting embedded combination of color appearance space and color appearance model that are desired by a user, or can be selected based on the manner in which the color management module constructs a color transform.

Preferably, as depicted in step S**904**, the color management module allows a user to select from one of many different color appearance spaces and from one of may different color appearance models to create a color transform for optimal color management results. In step S**905**, a source color transform and a source gamut boundary description are constructed based on the color characteristic data and viewing condition data extracted from the source color data file, in addition to the color appearance space and color appearance model utilized by the color management module. Next, it is determined whether the user wishes to save the generated source color transform and/or source gamut boundary description for future use (S**906**). If the source color transform and/or source gamut boundary description is to be saved, it is stored in a memory area such as a hard disk, floppy, CD-ROM or network server, as discussed above (S**907**), and flow then passes to step S**908**.

Next, a destination color transform and a destination device gamut boundary description are accessed in step S**908**. As discussed above, the destination color transform and destination gamut boundary description may be accessed from a traditional device color profile or may be generated in the same manner as the source color transform and source gamut boundary description according to steps S**901** to S**905** above. The source and destination gamut boundary descriptions are then used in conjunction with a gamut mapping algorithm to create a gamut transformation step for inclusion into the transformation sequence (step S**909**). The source color transform, the destination color transform and the gamut transformation step are then incorporated into a transformation sequence in step S**910**. In this manner, a comprehensive color transformation sequence is created for efficient end-to-end processing of color image data. It is then determined in step S**911** whether to save the transformation sequence for future use. If so, flow passes to step S**912** in which the transformation sequence is stored in a memory, such as a floppy, hard disk, CD-ROM, network server or the like. In either case, flow passes to step S**913** in which it is determined whether to apply the transformation sequence to the source color image data. If yes, the transformation sequence is applied to the source color image data to generate destination color image data in step S**914**. If not, flow passes to the end in step S**916**. If destination color image data was generated in step S**914**, the destination color image data is forwarded to the destination device for rendering of a color image (S**915**). Flow then passes to the end in step S**916**.

The present invention therefore provides a color data file for storing raw calorimetric measurement and device signal data corresponding to a source device in a standardized, format for subsequent use by a color management system to generate a source color transform. In this manner, a color management system is not forced to use a color transform that was originally created when the color image data was generated by the source device. A subsequent user of the color image data can then use a selected color management system having a preferred combination of a color space, a color appearance model and a desired set of viewing conditions in order to create a source device color transform.

Accordingly, a source device color transform does not have to be created until the color image data is subsequently accessed for use by a subsequent user. In this manner, color image data is associated with a corresponding source color data file that contains color characteristic data and viewing condition data of the source device in a well recognized, robust format for use by a variety of current, and not yet known, color management systems.

The invention has been described with respect to particular illustrative embodiments. It is to be understood that the invention is not limited to the above-described embodiments and that various changes and modifications may be made by those of ordinary skill in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A method for transforming source color image data from a source device into destination color image data for rendering by a destination device, wherein said method uses a color management module which has a source color transform generator for generating a source color transform, said method comprising the steps of:

obtaining the source color image data, wherein the source color image data is in a source color space corresponding to the source device;

obtaining a source color data file corresponding to the source device, wherein the source color data file contains source device color characteristic data, and wherein the source device color characteristic data contains calorimetric data and corresponding device signal data;

constructing a source color transform based on the source device color characteristic data contained in the source color data file, wherein said source color transform is constructed by using the source color transform generator, and wherein the source color transform transforms the source color image data to interim color image data in an interim color space; and

applying the constructed source color transform and a destination color transform to the source color image data to transform the source color image data from the source device color space into the destination color image data.

2. A method for transforming color data according to claim **1**, wherein the source color data file further contains viewing condition data corresponding to a set of viewing conditions in which the source device color characteristic data was measured.

3. A method for transforming color data according to claim **2**, wherein the viewing condition data includes ambient colorimetric specification data.

4. A method for transforming color data according to claim **2**, wherein the viewing condition data includes surround calorimetric specification data.

5. A method for transforming color data according to claim **2**, wherein the viewing condition data includes background calorimetric specification data.

6. A method for transforming color data according to claim **2**, wherein the viewing condition data includes adapting field colorimetric specification data.

7. A method for transforming color data according to claim **1**, wherein the device signal data represents a set of input command signal values for the source device.

8. A method for transforming color data according to claim **1**, wherein the calorimetric data represents a set of measured color values corresponding to a rendered color image.

9. A method for transforming color data according to claim **1**, wherein the device signal data represents a set of output command signal values from the source device.

10. A method for transforming color data according to claim **1**, wherein the colorimetric data represents a set of measured color values corresponding to a color image rendered by the source device.

11. A method for transforming color data according to claim **1**, wherein the source device is a printer, wherein the device signal data represents a set of input command signal values for the printer, and wherein the colorimetric data represents a set of measured color values corresponding to a color image rendered by the printer.

12. A method for transforming color data according to claim **1**, wherein the source device is a scanner, wherein the calorimetric data represents a set of measured color values corresponding to a rendered color image, and wherein the device signal data represents a set of output signal values from the scanner.

13. A method for transforming color data according to claim **1**, further comprising the step of incorporating the constructed source color transform and the destination color transform in a color transformation sequence, and wherein said step of applying applies the transformation sequence to the source color image data.

14. A method for transforming color data according to claim **1**, further comprising the step of constructing the destination color transform based on a destination color data file, wherein the destination color transform transforms color data from the interim color space to a destination device color space.

15. A method for transforming color data according to claim **1**, wherein the destination color transform is contained in a destination device color profile.

16. A method for transforming color data according to claim **1**, wherein the interim color space is a device-independent color space.

17. A method for transforming color data according to claim **1**, wherein the construction of the source color transform utilizes a color appearance model.

18. A method for transforming color data according to claim **1**, wherein the colorimetric data is in a standard color space.

19. A method for transforming color data according to claim **18**, wherein the standard color space is an XYZ color space.

20. A method for transforming color data according to claim **1**, wherein the construction of the source color transform is based on a type of the interim color space and a color appearance model.

21. A method for transforming color data according to claim **1**, wherein the source color transform is stored in a memory.

22. A method for transforming color data according to claim **1**, wherein the source color transform is stored in a device color profile.

23. A method for transforming color data according to claim **1**, wherein a source gamut boundary description is generated from the source color data file.

24. A method for transforming color data according to claim **23**, wherein the source gamut boundary description is used in conjunction with a destination gamut boundary description and a gamut mapping algorithm to create a gamut transformation.

25. A method for transforming source color image data from a source device into destination color image data for rendering by a destination device, wherein said method uses a color management module which has a source color transform generator for generating a source color transform, said method comprising the steps of:

obtaining the source color image data, wherein the source color image data is in a source color space corresponding to the source device;

obtaining a source color data file corresponding to the source device, wherein the source color data file contains source device color characteristic data, and wherein the source device color characteristic data is formatted according to a standard predetermined format and has a plurality of tags containing the source device color characteristic data and a set of viewing condition data corresponding to a set of viewing conditions in which the source device color characteristic data was measured;

constructing a source color transform based on the source device color characteristic data and the set of viewing condition data by utilizing an interim color space and a color appearance model, wherein said source color transform is constructed by using the source color transform generator and a color appearance model, and wherein the source color transform transforms the source color image data from the source device color space into interim color image data in the interim color space;

incorporating the source color transform in a color transformation sequence; and

applying the color transformation sequence to the source color image data to transform the source color image data into the destination color image data.

26. An apparatus for managing color data to transform source color image data from a source device into destination color image data for rendering by a destination device, comprising: a program memory for storing process steps executable to perform a method according to any of claims **1**, **2** to **12**, **13**, **14** to **16**, **17**, **18**, **19**, **20**, or **21** to **25**, and a processor for executing the process steps stored in said program memory.

27. Computer-executable process steps stored on a computer readable medium, said computer-executable process steps for managing color data to transform source color image data from a source device into destination color image data for rendering by a destination device, said computer-executable process steps comprising process steps executable to perform a method according to any of claims **1**, **2** to **12**, **13**, **14** to **16**, **17**, **18**, **19**, **20**, or **21** to **25**.

28. A computer-readable medium which stores computer-executable process steps, the computer-executable process steps to transform source color image data from a source device into destination color image data for rendering by a destination device, said computer-executable process steps comprising process steps executable to perform a method according to any of claims **1**, **2** to **12**, **13**, **14** to **16**, **17**, **18**, **19**, **20**, or **21** to **25**.

29. A method for managing color data to transform source color image data from a source device into destination color image data for rendering by a destination device, wherein said method uses a color management module which has a color transform generator, said method comprising the steps of:

accessing a source color data file of the source device and a destination color data file of the destination device, the source and the destination color data file containing colorimetric data and corresponding device signal data;

constructing a source color transform based on the source color data file by using the color transform generator; and

constructing a destination color transform based on the destination color data file by using the color transform generator;

generating a source gamut boundary description of the source device based on the source color data file, and a destination gamut boundary description of the destination device based on the destination color data file;

constructing a gamut transform based on the gamut boundary of the source device and the destination device gamut boundary description; and

applying the source color transform, the gamut transform and the destination color transform to the color image data.

30. A computer-readable medium which stores computer-executable process steps, the computer-executable process steps to transform source color image data from a source device into destination color image data for rendering by a destination device, said computer-executable process steps comprising process steps executable to perform a method according to claim **29**.

31. An apparatus for transforming source color image data from a source device into destination color image data for rendering by a destination device, said apparatus comprising:

a color management module which has a source color transform generator for generating a source color transform;

a first obtaining unit constructed to obtain the source color image data, wherein the source color image data is in a source color space corresponding to the source device;

a second obtaining unit constructed to obtain a source color data file corresponding to the source device, wherein the source color data file contains source device color characteristic data, and wherein the source device color characteristic data contains colorimetric data and corresponding device signal data;

a constructing unit constructed to construct a source color transform based on the source device color characteristic data contained in the source color data file, wherein said source color transform is constructed by using the source color transform generator, and wherein the source color transform transforms the source color image data to interim color image data in an interim color space; and

an applying unit constructed to apply the source color transform and a destination color transform to the source color image data to transform the source color image data from the source device color space into the destination color image data.

32. An apparatus for transforming source color image data from a source device into destination color image data for rendering by a destination device, said apparatus comprising:

a color management module which has a source color transform generator for generating a source color transform;

a first obtaining unit constructed to obtain the source color image data, wherein the source color image data is in a source color space corresponding to the source device;

a second obtaining unit constructed to obtain a source color data file corresponding to the source device, wherein the source color data file contains source device color characteristic data, and wherein the source device color characteristic data is formatted according to a standard predetermined format and has a plurality of tags containing the source device color characteristic data and a set of viewing condition data corresponding to a set of viewing conditions in which the source device color characteristic data was measured;

a constructing unit constructed to construct a source color transform based on the source device color characteristic data and the set of viewing condition data by utilizing an interim color space and a color appearance model, wherein said source color transform is constructed by using the source color transform generator and a color appearance model, and wherein the source color transform transforms the source color image data from the source device color space into the interim color image data in the interim color space;

incorporating the source color transform in a color transformation sequence; and

applying the color transformation sequence to the source color image data to transform the source color image data into the destination color image data.

33. An apparatus for managing color data to transform source color image data from a source device into destination color image data for rendering by a destination device, said apparatus comprising:

a color management module which has a color transform generator;

an accessing unit constructed to access a source color data file of the source device and a destination color data file of the destination device, the source and the destination color data file containing calorimetric data and corresponding device signal data;

a first constructing unit constructed to construct a source color transform based on the source color data file by using the color transform generator; and

a second constructing unit constructed to construct a destination color transform based on the destination color data file by using the color transform generator;

a generating unit constructed to generate a source gamut boundary description of the source device based on the source color data file, and a destination gamut boundary description of the destination device based on the destination color data file;

a third constructing unit constructed to construct a gamut transform based on the gamut boundary of the source device and the destination device gamut boundary description; and

an applying unit constructed to apply the source color transform, the gamut transform and the destination color transform to the color image data.

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